

WAFER STACK, INTEGRATED OPTICAL DEVICE AND METHOD FOR FABRICATING THE SAME

BACKGROUND OF THE INVENTION

[0001] b 1. Field of the Invention

[0002] The invention is in the field of integrated optical devices, in particular integrated camera modules with an image capturing element, such as a CCD sensor, and at least one lens element for imaging an object on the image capturing element, e.g. a refractive and/or diffractive lens. Integrated device means that all components are arranged in a well defined spatial relationship. Such integrated camera modules are, for example, cameras of mobile phones which are preferably manufactured in a mass production process at low cost.

[0003] More concretely, the invention relates to an optical device for a camera module comprising a baffle that defines a predetermined field of view (FOV) of the image capturing device, while suppressing beam paths coming from points outside this FOV. The invention further relates to a wafer scale package representing a plurality of such optical devices, to a baffle array with a plurality of baffles and to methods for manufacturing a plurality of camera modules and for manufacturing a baffle substrate.

[0004] 2. Description of Related Art

[0005] Especially in the field of mobile phones with cameras, but also for other applications, it is desirable to have a camera module that can be mass produced at low cost in an as simple process as possible and still has a good image quality. Such camera modules comprise an image capturing element and at least one lens element arranged along a common axis and are known from WO 2004/027880, for example. The known camera modules are manufactured on a wafer scale by replicating a plurality of lens elements on a disk-like substrate (wafer), stacking and connecting the substrates to form a wafer scale package (wafer stack) and dicing the stack in order to separate the individual camera modules from one another.

[0006] The camera modules are integrated optical devices, which include functional elements such as the image capturing device and the at least one lens stacked together along the general direction of light propagation. These elements are arranged in a predetermined spatial relationship with respect to one another (integrated device) such that further alignment with each other is not needed, leaving only the integrated device as such to be aligned with other systems.

[0007] Wafer-scale replication of lens elements allows the fabrication of several hundreds of generally identical devices with a single step, e.g. a single or double-sided UV-embossing process. Replication techniques include injection molding, roller hot embossing, flat-bed hot embossing, and UV embossing. As an example, in the UV embossing process, the surface topology of a master structure is replicated into a thin film of a UV-curable replication material such as an UV curable epoxy resin on top of a substrate. The replicated surface topology can be a refractive or a diffractive optically effective structure, or a combination of both. For replicating, a replication tool bearing a plurality of replication sections that are a negative copy of the optical structures to be manufactured is prepared, e.g. from a master. The tool is then used to UV-emboss the epoxy resin. The master can be a lithographically fabricated structure in fused silica or silicon, a laser or e-beam written structure, a diamond turned structure or any other type of structure. The master may also be a

submaster produced in a multi stage generation process by replication from a (super) master.

[0008] A substrate or wafer in the meaning used in this text is a disc or a rectangular plate or a plate of any other shape of any dimensionally stable, often transparent material. The diameter of a wafer disk is typically between 5 cm and 40 cm, for example between 10 cm and 31 cm. Often it is cylindrical with a diameter of either 2, 4, 6, 8 or 12 inches, one inch being about 2.54 cm. The wafer thickness is, for example, between 0.2 mm and 10 mm, typically between 0.4 mm and 6 mm.

[0009] If light needs to travel through the substrate, the substrate is at least partially transparent. Otherwise, the substrate can be nontransparent as well. In case of a camera module, at least one substrate bears electro-optical components, like the image capturing device, and may thus be a silicon or GaAs or other semiconductor based wafer; it may also be a CMOS wafer or a wafer carrying CCD arrays or an array of Position Sensitive Detectors.

[0010] Such integrated optical devices can be manufactured by stacking wafers along the axis corresponding to the direction of the smallest wafer dimension (axial direction). The wafers comprise functional elements, like lens elements or image capturing elements, in a well defined spatial arrangement on the wafer. By choosing this spatial arrangement in an adequate way, a wafer stack comprising a plurality of generally identical integrated optical devices can be formed, wherein the elements of the optical device have a well defined spatial relationship with respect to one another and define a main optical axis of the device.

[0011] By spacer means, e.g. a plurality of separated spacers or an interconnected spacer matrix as disclosed in US 2003/0010431 or WO 2004/027880, the wafers can be spaced from one another, and lens elements can also be arranged between the wafers on a wafer surface facing another wafer.

[0012] It is known to place a sunshade or baffle in front of the top lens element of a camera module. A sunshade or baffle is an element that defines a field of view (FOV) of the image capturing element by suppressing beam paths coming from points outside this FOV. Known baffles consist of a layer of non-transparent material having a given thickness in an axial direction and a through-hole for light transmission. The through-hole generally defines a cone with a given extent in the axial direction through which light can pass. The thickness as well as the shape of the side walls of the through hole determines the FOV and the maximum angle (collection angle) under which incident light can pass the baffle and enter the camera module. It is often desired that the collection angle does not exceed a predetermined value. This is because light entering the device under higher angles is stray light and/or may not directly fall onto the photosensitive part of the image capturing element but may hit the photosensitive part only after one or more reflections inside the camera module. This may lead to artifacts in the image generated by the image capturing element, and thus to a reduced image quality.

[0013] Known baffles have thus a thickness of several 100 μm (e.g. 100-300 μm) and side walls of the through hole which are tapered with an angle of 25-35° with respect to the normal direction of the front wall such that an opening with a varying cross section having a diameter in the range of 1-3 mm is formed. This restricts the full angle of the field of view to about 50 to 70°.

[0014] Known baffles are normally made as separate parts. They are attached to the integrated camera module only after its complete manufacture, i.e. after the dicing step if a wafer